Current and Future Patterns of Development in El Dorado County

A Case Study

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This case study describes a quantification of current patterns of development on the western slope of El Dorado County, a rapidly developing rural region of the central Sierra Nevada mountains, and a spatially explicit method to project future patterns of development. This analysis and projection methodology is part of a larger effort to model development in El Dorado County, and to assess the impacts of the development as well as the effectiveness of proposed land use policies. The study uses imagery and parcel data to develop a fine-grained picture (25-meter pixel) of current land cover, including urban and irrigated agriculture. It then projects future land cover based on a build out of the current General Plan, including very specific policies on riparian areas, steep slope and oak woodland canopy retention. These realistic future landscapes provide a basis for the assessment of impact on fire protection and environmental quality

Estimating the current pattern of development

U.S. Census Bureau data provide a uniform starting point for quantifying the pattern of development across California landscapes. Figure 1 shows the density of housing units on the western slope of El Dorado County according to the 1990 Census data. Purple and yellow areas are clearly urban or suburban. From a resource management and a fire protection perspective, the prevalence of structures is the most striking aspect of the landscape. At the other extreme the brown and black areas are so thinly settled that structures are incidental to fire protection and resource management. In the intermix, between the two extremes and shown in green and blue, the prevalence of structures affects but does not eliminate natural values and similarly influences but does not direct wildland fire control. These three intermix density classes—the blue and both greens—cover a large proportion of the county.

Understanding the landscape means understanding the intermix. The left panel in Figure 2 portrays the wildlands of El Dorado County, if lands with less than 1 housing unit per 160 acres are considered wild. Under this definition, the county wildlands appear as fragmented and isolated islands. This

Figure 1. Housing density on the western slope of El Dorado County

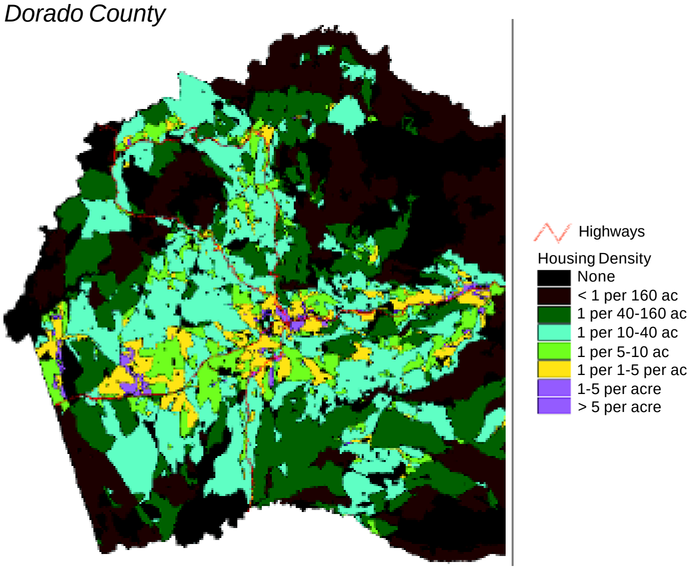
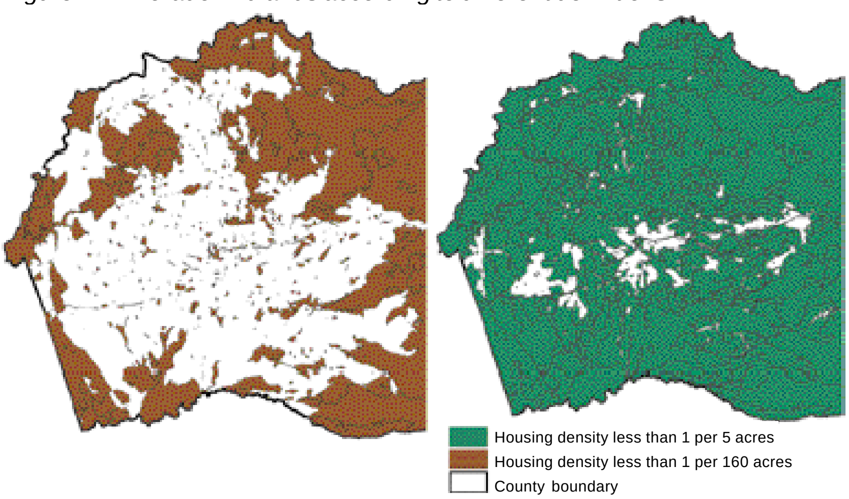


Figure 2. El Dorado wildlands according to different definitions



interpretation of the ecological impact of the County's settlement patterns differs considerably from that shown in the right panel, in which wildlands are more loosely defined as lands with less than 1 housing unit per 5 acres. In this case, the county wildlands are an extensive and connected mass. The true location and extent of wildlands lies somewhere in between but cannot be clearly linked to a particular settlement density. Much depends on exactly where and how settlement occurs in the intermix.

Currently available maps of land use do not clarify the location and nature of development within the intermix. Figure 3 shows general land cover for the western slope of El Dorado County as it appears to the Farmland Mapping Program (FLM) in 1988. The goal of this program is to delineate important agricultural lands and their conversion to other uses, so it is not surprising that it does little to clarify the pattern of rural settlement. It is included here because it is frequently used to delineate urban areas.

Figure 3. *Land cover types in 1988 from Farmland Mapping Program*

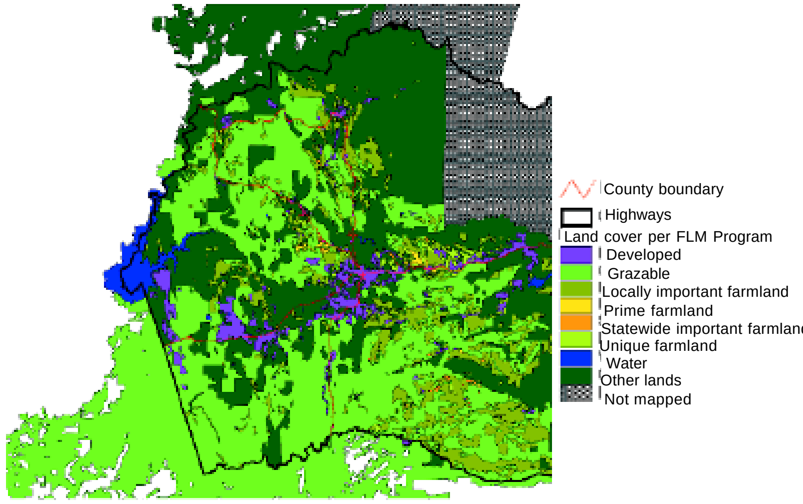


Figure 4. *FLM Developed class in relationship to Census data*

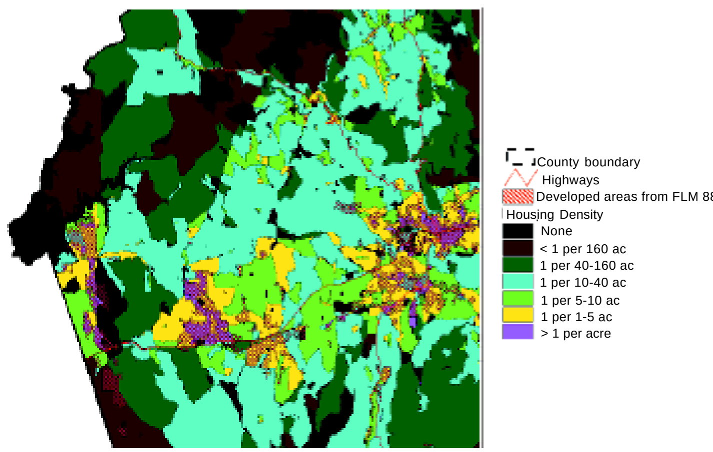


Figure 4 zooms into Cameron Park to show the clear correspondence of the densest Census classes with the FLM Developed class, and by contrast the numbers of houses in ex-urban areas not detected by FLM. Areas not labeled as Developed by FLM nevertheless include areas with housing densities up to one unit per acre (yellow in Figure 4). There is clearly much development outside of areas labeled as Developed.

Much finer grained data developed from imagery enhance our understanding of the intermix. The hardwood pixel data include two cover types, "urban" and "other", particularly important for this understanding. "Urban" denotes areas of high reflectance and portrays roofs, roads, and parking lots, as well as rock outcrops and bare soil. "Other" in El Dorado County generally corresponds to irrigated areas—pastures, vineyards, orchards and golf courses. Together they constitute the "footprint" of intense human use on the western slope. Figure 5 overlays "urban" or "other" pixels in and around Cameron Park on the Census data. In general, "urban" or "other"pixels are dense in areas of higher housing density, and less dense, in areas of lower housing density. The imagery locates the developed footprint within the intermix in ways not possible with Census or FLM data.[1]

Parcel data from El Dorado County improves the fine-grain picture of development available from imagery. The imagery may miss very developed areas that have a high canopy cover, such as in many older residential areas. Coding parcels according to their developed status, use and parcel size produces a map that more completely delineates densely developed areas. Combining that map with the pixel data that that accurately renders urban and suburban areas but also portrays the developed pixels within the intermix and even the wildland portions of the landscape. Figure 6 illustrates the combination of parcel and pixel data for the area between Cameron Park and El Dorado. (Gray areas are "unassigned" in the parcel database and

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[1]*Appendix 1 explains the methods to calculate the spatial statistics of urban or other pixels used to characterize different classes of development density.*

Figure 5. "Urban" or "other" pixels (25 m sq.) in relation to Census data and FLM Developed areas between Cameron Park and El Dorado

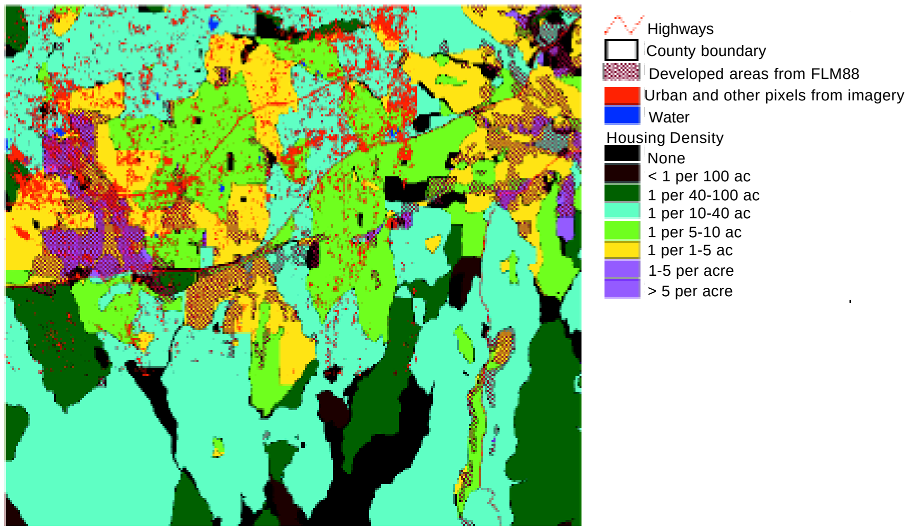
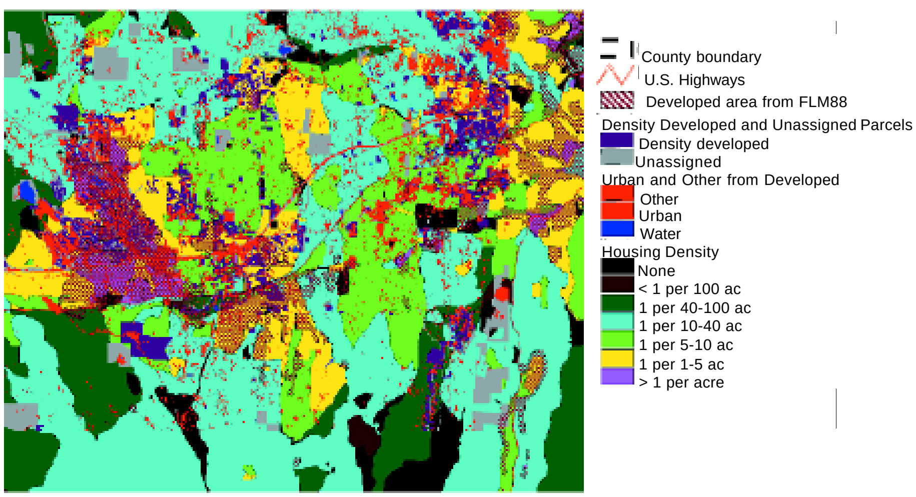


Figure 6. "Urban" or "other" pixels (25 m sq.) supplemented with Dense Developed Parcels (purple) in relation to Census data and FLM Developed areas between Cameron Park and El Dorado.



carry little information. In general, they are publicly owned by agencies such as the BLM or the BIA, or are road and highway rights-of-way.) Figure 7 combines all data sources to portray a best estimate of the current extent of development along U.S. 50 from Sacramento County to Placerville.[2]

Predicting the future pattern of development

The land use element of the El Dorado County General Plan provides the broad picture of housing densities allowable at buildout through its maps of land use designations (LUDES). Figure 8 portrays LUDES using housing density classes and colors comparable to those used with the Census data.[3]

[2] *Appendix 2 explains how the intersection of pixel and parcel data leads to several adjustments in the data in pursuit of the best estimate of current development.*

[3] *Appendix 3 in the Appendices explains the relationship between Census density classes and General Plan LUDES.*

The method uses density classes established by the General Plan to create pixel maps of simulated future development (i.e., similar in appearance to Figure 7). The method assumes that the density and distribution of urban or other pixels that existed in 1990 in a given Census density class will characterize all the area within the corresponding LUDES class at buildout. Put another way, this method assumes that buildout does not change the spatial pattern of settlement that occurs at a given density. Rather it simply controls its extent, with several exceptions noted below.

Some areas within LUDES classes are not open to development. Parcels already developed to densities allowed by the General Plan, public lands and lakes constitute the most obvious locations that are "off limits" to future development. General Plan policies apply only to parcels for which future development will require a discretionary permit from the County Planning Department. These policies create riparian buffers and steep slope exclusion zones, and requires retention of some or all tree canopy, all of which preclude additional development of specific areas. Figure 9 shows in red those areas that these constraints will remove from the pool of potentially developable lands.[4]

Figure 7. Location and exent of development along U.S. 50 in El Dorado Country from Sacramento County to Placerville

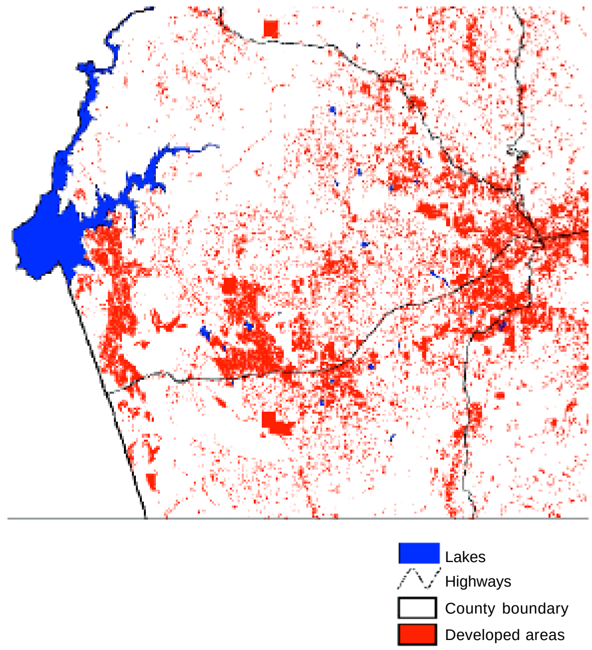
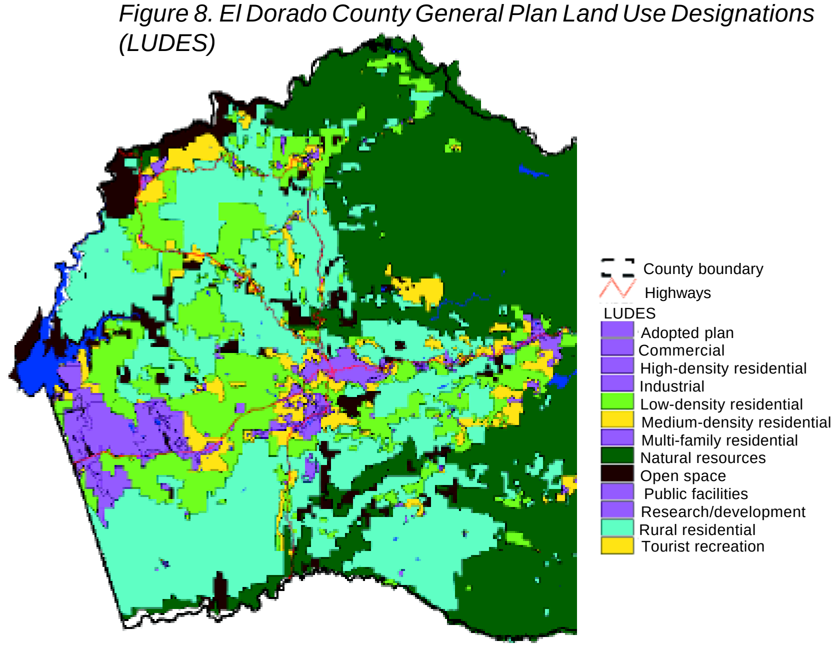


Figure 8. El Dorado County General Plan Land Use Designations (LUDES)



[4] *Appendix 4 explains how this analysis locates and models General Plan policy constraints on future development.*

Figure 9. Red pixels denote all areas from which development is excluded because of existing development, ownership, slope or riparian exclusion policies, or complete canopy retention.

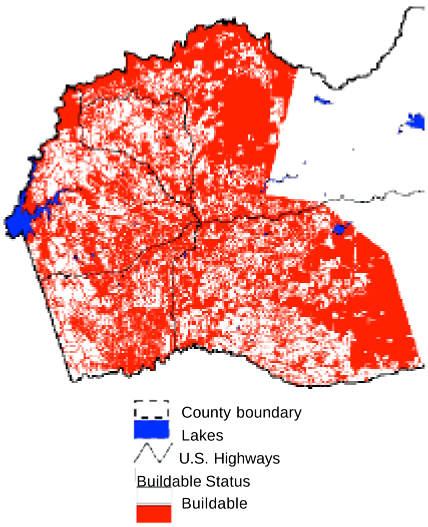
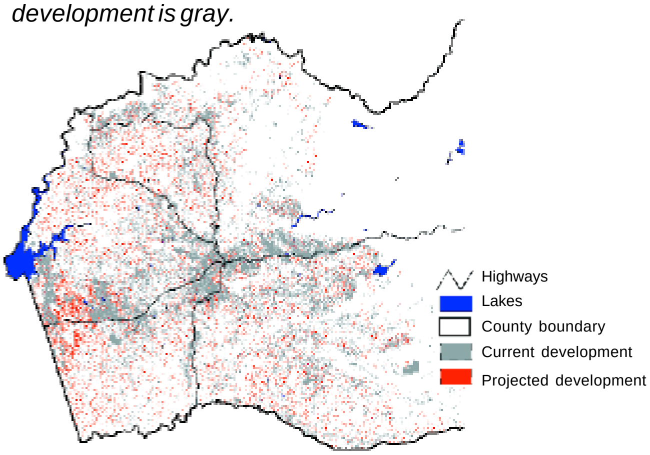


Figure 10. Simulated additional development for a portion of the western slope of El Dorado County. Additional development at buildout is red and existing development is gray.



Filling in buildable areas with patterns typical of the LUDES classes for those areas generates one possible configuration of the buildout landscape. The project generally produces three realizations of a given scenario, such as buildout, in order to assess the degree to which chance location of development alters overall impact. Figure 10 shows one realization of buildout against the backdrop of existing development. While Figure 10 shows more intense development near U.S. 50, it nonetheless shows a considerable amount of development scattered through areas that are currently nearly empty of structures.[5]

Projected population increases at buildout on the western slope of El Dorado County range from 108,000 to 255,000. The analysis supports estimates of population growth at buildout based on assumptions of residential densities, household sizes and the extent of "grandfathered" parcels. Census blocks already developed to densities characteristic of the General Plan LUDES generally show average parcel sizes larger than the minimum size allowed by the LUDES. This pattern could continue or it could increase in density up to the limit set up LUDES. In addition, the 1990 Census data show that household size differs across density classes with smaller households at both ends of the density range. This pattern could similarly continue into the future, or one could assume that households in all LUDES would increase in size. Finally, "grandfathered" parcels—existing parcels smaller than the minimum allowed by the General Plan—can increase the expected population growth particularly in lower density LUDES.

Subsequent case studies describe the land use policy scenarios investigated as well as the impacts of development under each scenario on oak woodland habitat, expected losses from wildfire and other values.

[5] *Appendix 5 explains the methods used to model the spatial pattern of development at buildout.*

Table 1. Summary table of estimated population growth at buildout

Estimating Population Growth at Buildout	Ignoring grandfathered parcels: density assumption applies throughout the buildable area		Considering grandfathered parcels: density rules apply only to parcels larger than the minimum established by LUDES; smaller parcels each support one new household	
Density and household size assumptions	Number of people	Number of houses	Number of people	Number of houses
Buildable areas are developed to densities characteristic of, and by households with size similar to, those found in 1990 Census density classes	108494	53753	119350	58610
Buildable areas are developed to the maximum densities allowed by the General Plan by households with size similar to those found in 1990 Census density classes	205649	102037	213984	105829
Buildable areas are developed to the maximum densities allowed by the General Plan by households similar to the largest household size found in 1990 Census density classes	245571	102037	254738	105829

Appendices

Appendix 1. Spatial statistics characterizing landscapes with different densities of development

A principal objective of this analysis is to provide spatially explicit (25-m pixel) images of likely future developed landscapes, particularly those associated with build-out of the General Plan. The development of these images requires a means to generate spatially explicit patterns of development within areas slated by the General Plan (or any other scenario) to be developed to particular housing densities. For instance, the General Plan identifies areas that will be developed as Low Density Residential (LDR, 5-10 acres per housing unit). This analysis fills open land within LDR with a 25-m pixel image of land cover typical of that residential density

The analysis creates this image with a space-filling algorithm that uses two spatial statistics:

· B, the density of urban or other pixels, that is the total percentage of the area classified as "urban or other" (the unconditional probability that a pixel picked at random would be "urban or other"), as well as

· C, the spatial contagion (i.e., the "clumpiness") of urban or other pixels (the conditional probability that the neighbor of an "urban or other" pixel is itself an "urban or other" Pixel).

The analysis calculates the values for B and C used by the algorithm for five different classes of housing densities by looking at subsets of the El Dorado County landscape that epitomize those different density classes. The 1990 Census blocks distinguish areas within the county already developed to particular densities corresponding to those used by the General Plan. By overlaying the Census blocks on the hardwood pixel data, the analysis locates subsets of the landcover data that correspond to the Census density classes (see hyperlinked examples in Table 1.1 below). From those subsets of landcover data, this analysis calculates the density and contagion statistics.

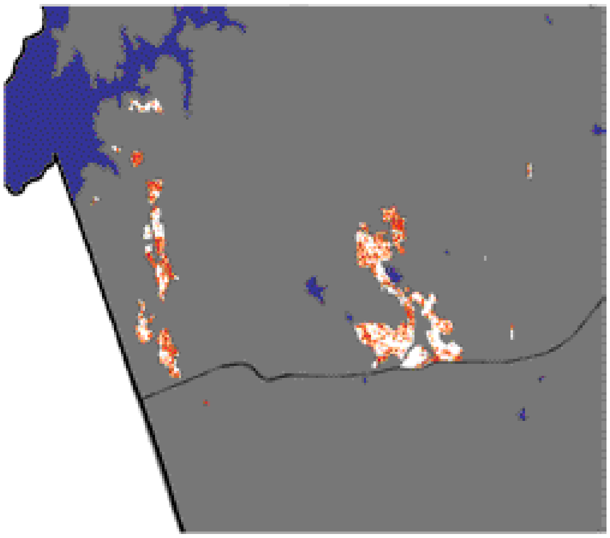
Table 1.1. Density and contagion of urban or other pixels on the western slope of El Dorado County within areas ('strata') shown by the 1990 Census to be developed to densities corresponding to those used by the General Plan.

Density Class (Census Housing Density Class or "denclass")	Corresponding General Plan Residential Land Use Designation (LUDES)	Density (percent of total area in urban or other,"B value")	Contagion factor (given that a cell is urban or other, probability that a neighboring cell is also urban or other "C value")
>1 housing unit/acre (7,8) (see Figure 1.1)	HDR,MFR	27	.62
<=1 h.u./acre and > 1 h.u./5 acres (6)	MDR	14	.61
<= 1 h.u./5 acres and > 1 h.u./10 acres (5) (see Figure 1.2)	LDR	9	.55
<=1 housing unit/10 acres and > 1 h.u. per 40 acres (4)	RR	6	.55
<=1 housing unit/40 acres and >=1 h.u./160 acres (3)	NR	3	.50

MFR = multi-family residential
HDR = high density residential
MDR = medium density residential
LDR = low density residential
RR = rural residential
NR = natural resources

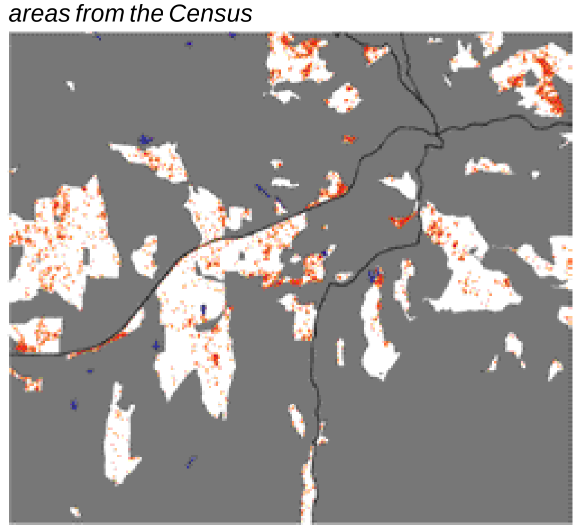
These different B and C values drive a space-filling algorithm developed by Kevin McKelvey and Jennifer Crocker (1996 for this simulation of fire patterns and adapted by the authors to simulate the pattern of new development (see Appendix 5) within areas slated for development at different housing densities. For instance, within the area of the county slated for development at densities between one housing unit/five acres and one h.u./10 acres, the algorithm would spread a pattern of urban or other pixels that covered 9% of the available space and that slightly clumped the urban or other pixels.

Figure 1.1 Urban or other pixels in high density areas from the Census



The gray area masks out all areas with housing densities less than one housing unit per acre. Therefore, the unmasked portions show only areas with current densities comparable to those in the most intense land use designations of the General Plan. Within these areas of high density (El Dorado Hills and Cameron Park), red indicates urban or other pixels in the hardwood pixel data set. Not every pixel within even densely settled areas appear as urban or other. However, urban or other pixels are frequently clumped, much more so than in less dense areas.

Figure 2.1 Urban or other pixels in moderately dense areas from the Census



The gray area masks out all areas with housing densities either greater than one housing unit per five acres or less than one housing unit per 10 acres. The portion unmasked has densities of one housing unit per five to 10 acres, a density labeled as Low Density Residential by the General Plan. Within these areas, as shown along U.S. 50 between Shingle Springs and Placerville, red indicates urban or other pixels in the hardwood pixel data set. Less of the area is covered by “urban or other” than in higher density areas from the Census and, while clumps are visible, many single pixels occur.

Appendix 2. Using parcel data to assess and improve landcover pixel data

The intersection of pixel and parcel data allows several adjustments to the data in pursuit of the best estimate of current development. The analysis first classifies the parcel data into a smaller number of meaningful classes. Then hardwood pixel data are overlaid by the parcel data and rates of errors extracted. These error rates suggest ways to augment the hardwood pixel data to produce a more accurate image of existing development.

The classification of parcels

The El Dorado County parcel coverage supports a classification of parcels along three dimensions. The first axis involves the status of the parcel as vacant, developed or unassigned. *Vacant* refers to privately owned parcels lacking taxable improvements; generally, they are *raw* land. *Developed* refers to parcels that have taxable improvements, such as structures. Subsequent investigation shows some conflicts between the developed status of parcels and the value of their improvement. However, this analysis considers a parcel as developed if it is so labeled in the database. *Unassigned* generally refers to land that does not generate property tax revenue and therefore consists mostly of public land and public roads. By overlaying unassigned parcels on ownership it is possible to distinguish between roads and the public lands. Some unassigned parcels fit neither profile and are private parcels assumed to be subject to development. These parcels were isolated and coded as *vacant*.

The second axis involves the intensity of development on developed parcels: either densely or not densely developed. The analysis split developed parcels into *densely developed* and *not densely developed* according to the primary use code. Densely developed parcels are those that by a combination of size and use cannot maintain the full range of wildlife habitat values within the parcel, while not densely developed may maintain some habitat values somewhere within the parcel.

Finally, the analysis determines the conditions under which further development of a parcel will occur: a parcel may be open to further development without restriction, open with restriction, or closed. *Restriction* means subject to discretionary permit review by the Planning Department. Without restriction means with ministerial approval, epitomized by a building permit. An overlay of the parcels on the General Plan determines the conditions under which further development can occur. Some developed parcels are already of a size congruent with their General Plan Land Use Designation (LUDES). Therefore, such parcels, both densely and not densely developed, are built out and closed to further development. Some vacant and developed parcels may be of a size considerably larger than their General Plan LUDES. Such parcels will most likely undergo some form of subdivision or other discretionary permit review before they are further developed. Thus, these parcels are open to development with the restrictions imposed by General Plan policies. Finally, some vacant parcels may be of size congruent with their General Plan LUDES. Development of those parcels requires a building permit, not discretionary permit review by the Planning Department. General Plan policies will not apply to these parcels.

The interaction of these axes yields the following combinations:

Table 2.1 portrays the development status and availability for future development for all parcels according to their current primary use as given by the County Assessor's data and General Plan land use designation. For certain combinations of primary use and LUDES, different parcel sizes lead to different development status. Figure 2.1 portrays the spatial pattern of development status.

Development Status	Interpretation
Unassigned; Federal or state ownership	Assumed to be public land and therefore vacant and closed
Unassigned but not Federal or state ownership	Assumed to be roads and therefore densely developed and closed
Vacant, closed	Vacant private land within open space designation
Vacant, open without restriction	Already subdivided land, ready for a building permit
Vacant, open with restriction	Parcel that can be further subdivided per the General Plan, subjected to Planning Department review
Densely developed, closed	Improved parcel with little habitat value, near the minimum size allowed by the General Plan: no further development possible
Densely developed, open with restrictions	Improved parcel with little habitat value, of a size that allows further subdivision under the General Plan, subjected to Planning Department review
Not densely developed, closed	Improved parcel with potential habitat value, near the minimum size allowed by the General Plan: no further development possible
Not densely developed, open with restrictions	Improved parcel with potential habitat value, of a size that allows further subdivision under the General Plan, subjected to Planning Department review

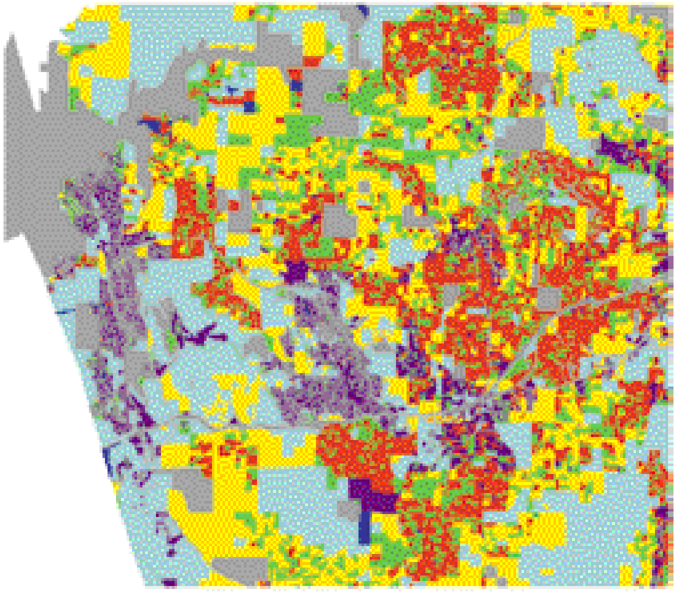
The assessment of the accuracy of the classified imagery

The hardwood pixel data, community regions from the General Plan, Census housing density classes and the County Assessor's parcel data provide independent perspectives on the current extent of development on the western slope. While the different minimum mapping units of these coverages prevent any direct comparison, overlays of urban or other pixels on coverages of community regions, Census housing density classes and parcels, leads to three different levels of assessment of the accuracy of the classified imagery.

Visual correspondence with Community Regions

Community Regions are areas defined by the General Plan as "appropriate for the highest intensity of…urban development and suburban type development…based on the municipal sphere of influence." Since they are defined around the existing settlement pattern, we should expect urban and other pixels to be very evident within Community Regions. At a coarse scale the overlay shows this assumption to be correct: the "urban or other" pixels data are congruent with the current settlement pattern of the western slope of the county. Urban and other pixels are not randomly located in the image of western El Dorado County but appear spatially correlated with community areas. Figure 2.2 shows the location of "urban or other" pixels with respect to County Community Regions.

Figure 2.1 Parcel development status and availability for future development, western El Dorado County



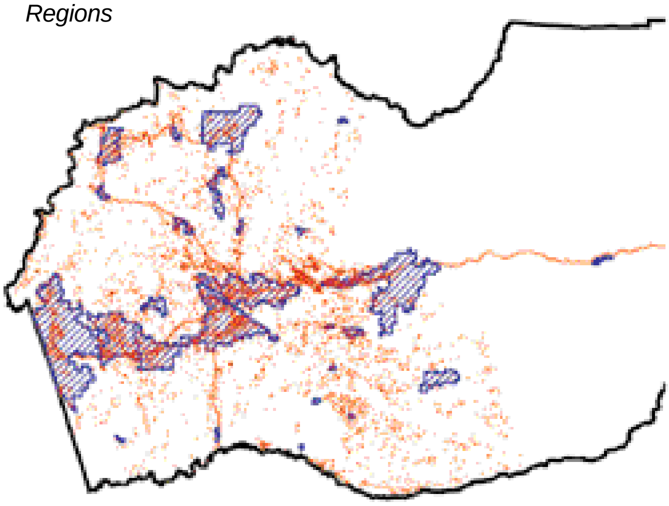
Correlation within Census density strata

Similarly, one would expect urban and other pixels to be concentrated within the Census blocks with higher housing densities. That expectation is borne out. The proportion of density strata (composed of census blocks) covered by “urban or other” pixels (the “B” value; see Table 1.1) increases with housing density.

However, is there any relationship between the **degree** of development within those Census blocks, as quantified by the parcel data, and the density of urban or other pixels? Table 2.2 and Figure 2.3 below portray the relationship between the B value calculated for all Census blocks stratified by housing density class and the following two values calculated from the parcel data for those same strata or classes:

- the proportion of the **number** of parcels within the density class labeled as *developed* (e.g., 56 out of 100 parcels, or 0.56, labeled as “developed”), and
- the proportion of the **area** of the class within parcels labeled “developed” (e.g., “developed” parcels cover 0.45 of density class area).

Figure 2.2 Urban or other pixels and County Community Regions



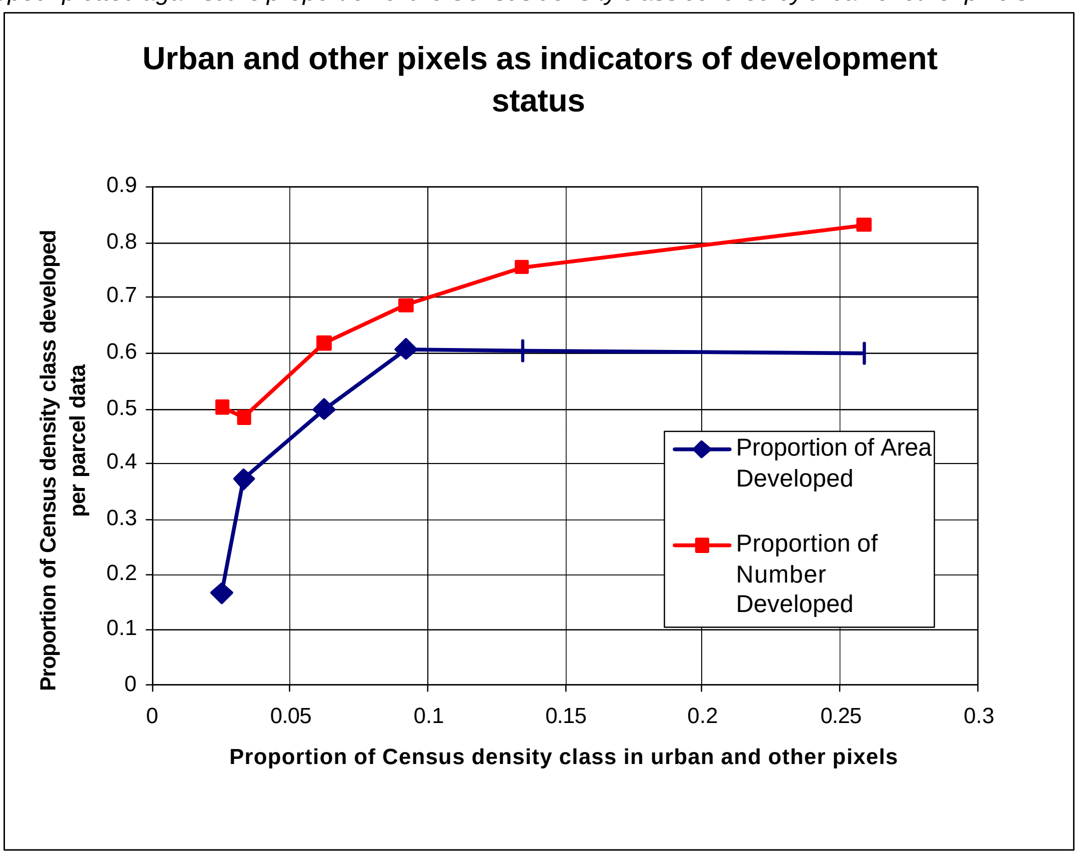
The planning regions are the “spheres of influence” of existing communities. The urban or other pixels in the imagery appear spatially correlated with the planning regions. The large area of urban or other pixels not within a planning region (in the center of the county) is the vineyard and orchard area of Apple Hill and is therefore correctly classified as part of footprint of human use in El Dorado County.

The total area of developed sites within developed parcels—that is, the actual footprint of development that one would expect to detect with aerial photography or satellite imagery—should exceed this limit. If it does, then some undeveloped parcels must in fact contain developed sites. Conversely, to the extent that developed parcels leave some vegetation intact, the proportion of the density class included in the actual footprint of development will be less than this number.

Table 2.2 B value, proportion of parcels labeled as "developed", and proportion of total area with parcels labeled as "developed" by Census housing density class.

Census housing density class	Proportion of class classified as urban or other (B)	Proportion of parcels within class labeled as "developed"	Proportion of class area within parcels labeled as "developed"
> 1 h.u. per 160 acres	0.025	0.50	0.17
<=1 housing unit/40 acres and >=1 h.u./160 acres	0.033	0.49	0.37
<=1 housing unit/10 acres and > 1 h.u. per 40 acres	0.063	0.62	0.50
<= 1 h.u./5 acres and > 1 h.u./10 acres	0.092	0.69	0.61
<=1 h.u./acre and > 1 h.u./5 acres	0.134	0.76	0.60
>1 housing unit/acre	0.258	0.83	0.60

Figure 2.3 Proportion of parcels labeled as "developed", and proportion of total area with parcels labeled as "developed" plotted against the proportion of the Census density class covered by urban or other pixels



The nearly linear relationship between the proportion of the total number of parcels developed in a density class and the proportion of the area occurring as *urban or other* pixels—the red line in Fig. 2.3—suggests a relationship between the land cover label in the hardwood pixel data and the developed landscape. If development actions within a parcel convert a fixed extent of land to *urban or other* (the *developed site*), independent of the size of the parcel, then all other things being equal, one would expect such a linear relationship between the two measures. Departures from linearity could result from unequal numbers of parcels per density class and from a non-fixed relationship between class density and the size of the developed site. For example, if the actual developed area within a parcel declined at higher density, then one would expect the curve to decline at higher densities, as it does.

Assuming that the classified imagery is detecting development in this way, then the extrapolation of the red curve in Figure 2.3 suggests that in high density, nearly built-out landscapes (Y-axis values approaching 100 percent), the total proportion of land devoted to development (X axis) would not exceed 0.4-0.6 of the landscape. Based on personal observation, this conclusion seems to underestimate the final scope of buildout. Thus, it may be that the classified imagery detects only a fraction of the developed sites because of masking by overstory vegetation. If that detection percentage remains constant across strata, then the two variables would still maintain a linear relationship. If, however, the detection rate declined with increasing density (from urban planting, etc.) then one would expect the rate to decline with increasing density as it does.

This proposed relationship between the parcel data and the landcover data at this scale is neither contradicted nor confirmed by the quadratic nature of the relationship between the proportion of total area in developed parcels and the proportion of the landscape in urban or other pixels- the blue line in Figure 2.3. Certain assumptions can render both curves consistent with the proposed concept of the *developed site.*

The steep rise at the lowest two densities in the proportion of area within developed parcels (the blue line), while the proportion of developed parcels remains constant (the red line), indicates that average developed parcel size at the lowest density must be **smaller** than in the next to lowest density class. Examination of the parcel data (see Table 2.3) shows this situation to be the case. Developed parcels in those lowest density classes are an order of magnitude smaller than the class definition would lead one to believe. Thus, they are actually pockets of denser development within a wildland matrix.

The flat portion of the curve at higher density classes indicates that as density increases, parcel sizes fall fast enough to counteract their increased numbers, holding the sum of developed site area in developed parcels constant. As long as parcel sizes remain considerably larger than the size of the hypothesized *development site* within a parcel, both the proportion of the landscape appearing as *urban or other* and the proportion of parcels labeled as *developed* can increase with density without requiring the area within developed parcels to increase.

Thus, at the Census housing density class level, the density of urban or other pixels from the hardwood pixel data appears correlated with the incidence of development. Detection of a similar fraction of developed sites, themselves of similar size, within parcels across housing density classes is consistent with the data.

Pixels as predictors of parcel development status

Leaving housing density classes and moving to the much smaller scale of individual parcels within classes, how well do urban and other pixels correlate with development status of parcels? In general, if the land cover data were perfect, one would expect that:

·Parcels listed as *vacant* would not contain any urban or other pixels

·Parcels listed as *develope*d would contain at least one urban or other pixel

Data are rarely perfect. Overlays uncover both errors of commission (in this case, urban or other pixels in vacant parcels, or false positives) and errors of omission (developed parcels with no urban or other pixels, or false negatives). Figure 2.4 below overlays the urban or other pixels on top of the parcel data in the area around Shingle Springs and provides a visual example of the data portrayed in Table 2.3.

The data in Table 2.3 support the concept of a shrinking developed site within parcels with increasing density of the housing density class. The average number of *urban or other* pixels per detected developed parcel varies from around six (roughly one acre, with an average detected parcel size of 14 acres) at the lowest densities to around two (0.33 acres, with an average detected parcel size of 0.5 acres) at the higher density.

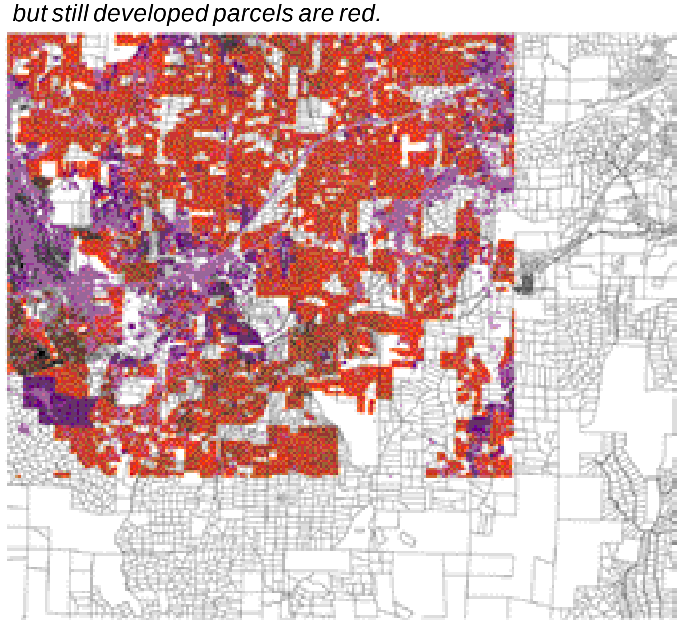


Figure 2.4 Urban or other pixels overlaid on developed parcels, dense and not dense. Urban or other pixels are magenta. Dense developed parcels are purple, not dense but still developed parcels are red.

If one assumes that every developed parcel has within it a developed site, then the classified imagery detects only a subset of those developed sites. The detection rate (number of developed parcels with *urban or other* pixels/ number of all developed parcels) declines from 44-48 percent at the lowest densities to 40 percent at the highest density. (It is important to note that not all parcels labeled as *developed* in the parcel database appear by their valuation of improvements to be developed in the sense used here. It is possible that the detection rate is in fact somewhat better than reported here). The decline in detection rate (increase in errors of omission) and the consistently smaller average parcel size for undetected parcels within a class are consistent with the hypothesized increase in masking by canopy at higher housing densities.

On the other hand, the overlay also shows errors of commission: falsely labeling undeveloped parcels as developed because of the presence of land covers, such as rocks or bare soil, that are spectrally similar to *urban or other*, and therefore misclassified as such.

Errors of commission are high at low densities—half of the parcels containing urban or other pixels in the lowest density class are vacant according to the parcel data. Looked at another way, 50-70 percent of the *urban or other* pixels in the lowest density strata occur in parcels labeled as vacant by the parcel data. **This parcel error rate declines to around 20 perdent at the highest density**, with 37 percent of the *urban or other* pixels in apparently vacant parcels. (A certain portion of the *urban or other* pixels may in fact be roads in unassigned parcels, which are considered vacant in this analysis, particularly at higher densities.)

Given these errors, what can we conclude about the use of hardwood pixel data for characterizing existing development and for modeling future development? The errors of omission and commission tend to cancel each other in such a way that the B value calculated from the classified imagery may approach the true value. If one estimates a corrected B value (see Table 2.4 below) by (1) adding urban and other pixels on the assumption that all developed parcels within a density class have a developed site equal in size to that of detected developed parcels; (2) subtracting the number of urban or other parcels in vacant parcels; and (3) dividing by the total number of pixels in the density class, the resulting corrected B values differ only slightly from those calculated from the imagery. The B values calculated from the imagery slightly overestimate development at lower densities, based on the corrected B, and slightly underestimate development at the highest density.

Table 2.4 B values measured from the imagery compared to B values calculated using parcel data

Imagery B	Corrected B
0	-0.2
3	1.8
6	4.2
9	8.8
14	14.9
27	31.4

Supplementing the imagery through addition and deletion

By using landcover and parcel data together, the analysis supports four types of changes to the landcover data that generate a more accurate picture of current development.

1. *Urban or other* pixels in certain types of vacant parcels are treated as false positives. *Urban or other* pixels in vacant parcels are not treated as developed in subsequent steps of this analysis and are relabeled as barren, unless the parcels are within an Agricultural District, or have a LUDES of Industrial, Commercial, Research/Development or Public Facilities. In these classes, there is a high likelihood that the urban or other pixels are not natural features of the landscape, but are related to human activity—either agriculture or site modification prior to building—and, therefore, should be considered as part of the footprint of development. This is true even though the County Assessor considered the parcel as vacant.

2. *Urban or other* pixels in unassigned parcels that intersect spatially with government ownership are similarly relabeled as barren and not considered part of the footprint of development. *Urban or other* pixels in unassigned parcels that do not intersect with government ownership are generally associated with roads in settled areas. Therefore, they remain *urban or other* and contribute to the footprint of development.

3. All pixels within densely developed parcels are treated as *urban or other*. Developed parcels are labeled as either densely developed or not densely developed according to their primary use code and, for some codes, their size (Table 2.1). All pixels within densely developed parcels retain their original land cover label, but subsequent steps in the analysis consider them as equivalent to *urban or other* and pool them with the *urban or other* pixels from the imagery.

4. Low density development is simulated within parcels that lack any *urban or other* pixels but are labeled as not densely developed. In this case, the parcel presumably contains a developed site that escapes detection by the imagery. Not all pixels within such parcels should be considered as developed. Some areas within those parcels are likely to be equivalent to *urban or other* pixels, but others probably remain relatively unaltered. This analysis simulates a development pattern within those parcels appropriate to the average parcel size (Table 2.5). For instance, parcels with undetected development in areas currently developed at the LDR density have average parcel sizes more typical of current MDR (see Table 2.3). Thus, the development simulated within those parcels has the spatial characteristics (B and C) typical of current MDR areas.

Table 2.5 Average size and B value used for simulation within developed but undetected parcels by current structural density class of U.S. Census

Current structural density class (corresponding LUDES)	Average Size of Undetected Developed Parcel (acres)	B value and associated LUDES used to simulate undetected development
3 (NR)	8	.09 (LDR)
4 (RR)	5	.09 (LDR)
5 (LDR)	2	.14 (MDR)
6 (MDR)	1	.27 (HDR)
7 & 8 (HDR, MFR)	>0.5	.27 (HDR)

Appendix 3. Relationship between Census density classes and General Plan LUDES

The General Plan Land Use Designations (LUDES) describe the types and densities of development anticipated by the General Plan. The density descriptions correspond closely with housing density classes available from the 1990 Census (Table 3.1). Particular designations that lack specific allowable densities are all relatively high impact land uses and, as such, are associated with the densest Census housing density classes. Because of this close correspondence, it is possible to portray the County's current condition (Figure 3.1) and its condition under build-out (Figure 3.2) using the same classification.

Table 3.1 General Plan Land Use Designations (LUDES), allowable densities, U.S. Census Housing Density Classes and corresponding housing density thresholds, and B and C statistics used to project buildout into undeveloped parcels

Land Use Designation (code)	Allowable Density per General Plan	Housing Density Class based on Census data(description)	B (proportion built out) and C(contagion)
Open Space (OS)	None	1 (none) 2 (>160 acres/housing unit)	0,0
Natural Resources (NR)	40-160 acres/dwelling unit (d.u.)	3 (40-160 acres/housing unit)	.03,.50
Rural Residential (RR)	10-160 acres/d.u.	4 (10-40 acres/housing unit)	.06,.55
Low Density Residential (LDR)	5-10 acres/d.u.	5 (5-10 acres/housing unit)	.09,.55
Medium Density Residential (MDR)	1-5 acres/d.u.	6 (1-5 acres/housing unit)	.14,.61
High Density Residential (HDR)	1-5 d.u/acre	7 (1-5 housing units/acre)	.27,.62
Multi-Family Residential (MFR)	5-24 d.u./acre	8 (>5 housing units/acre)	.27,.62
Adopted Plan (AP)	n.a.	[7 & 8]	.27,.62
Industrial (I)	n.a.	[7 & 8]	.27,.62
Commercial (C)	n.a.	[7 & 8]	.27,.62
Research and Development (RD)	n.a.	[7 & 8]	.27,.62
Public Facilities (PF)	n.a.	[7 & 8]	.27,.62
Tourist Recreation (TR)	n.a.	[7 & 8]	.27,.62

Figure 3.1 1990 Census Housing Unit Density Per Acre

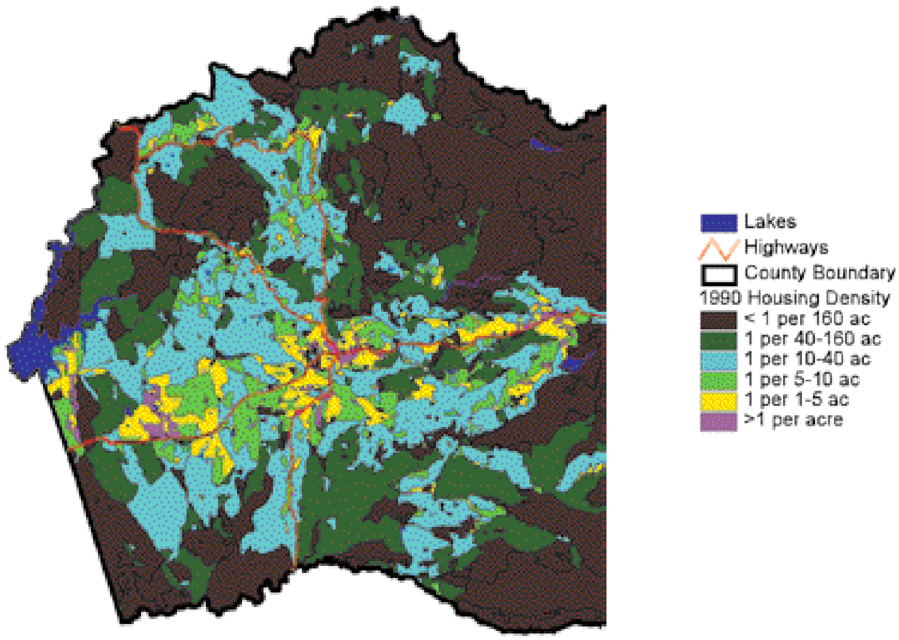
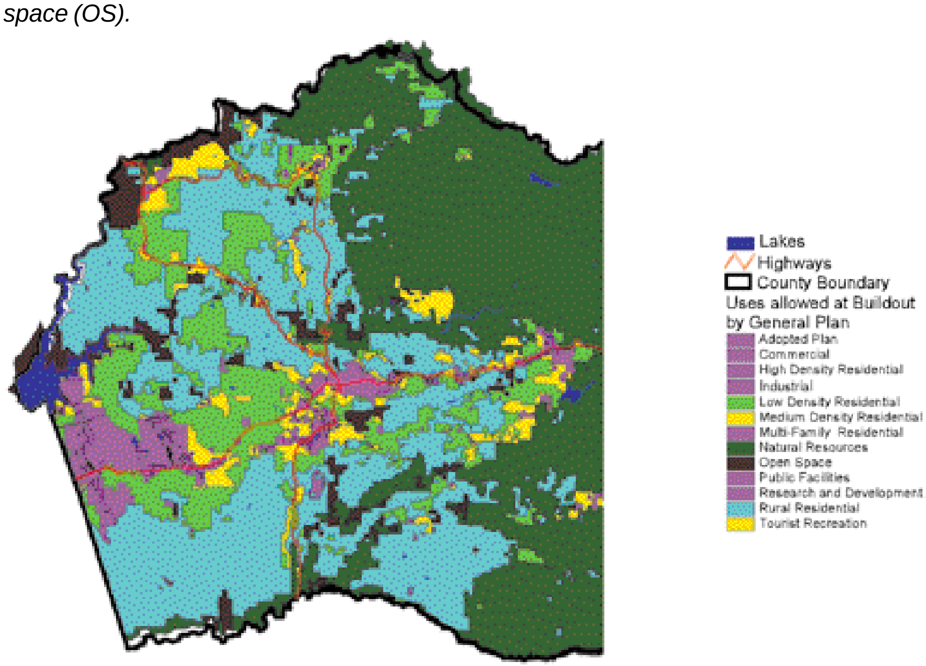


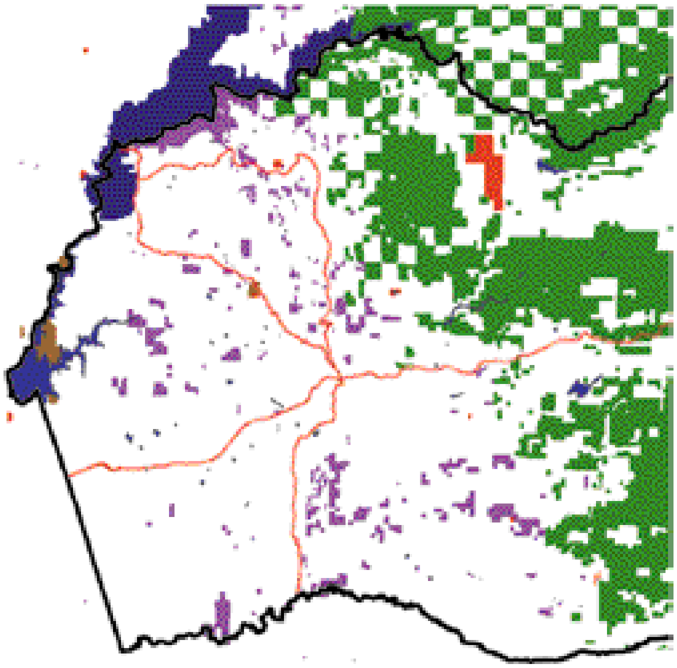
Figure 3.2 General Plan Land Use Designations. Colors correspond to residential densities as shown for Figure 1 and show residential densities allowed or impacts to be expected at buildout of the General Plan. Note that the Plan does not portray USFS ownership as open space (OS).



Appendix 4. Locating and modeling General Plan policy constraints on future development

Ownership

Figure 4.1 Ownership of the western slope, El Dorado County. All public lands are excluded from subsequent development; they are part of the "nobuild" area.



Public ownership of land is the simplest constraint on development. All pixels within state or federal ownership are therefore part of the *no build* area. Figure 4.1 portrays the public ownership pattern on the western slope of the county.

Parcels built out and closed to further development

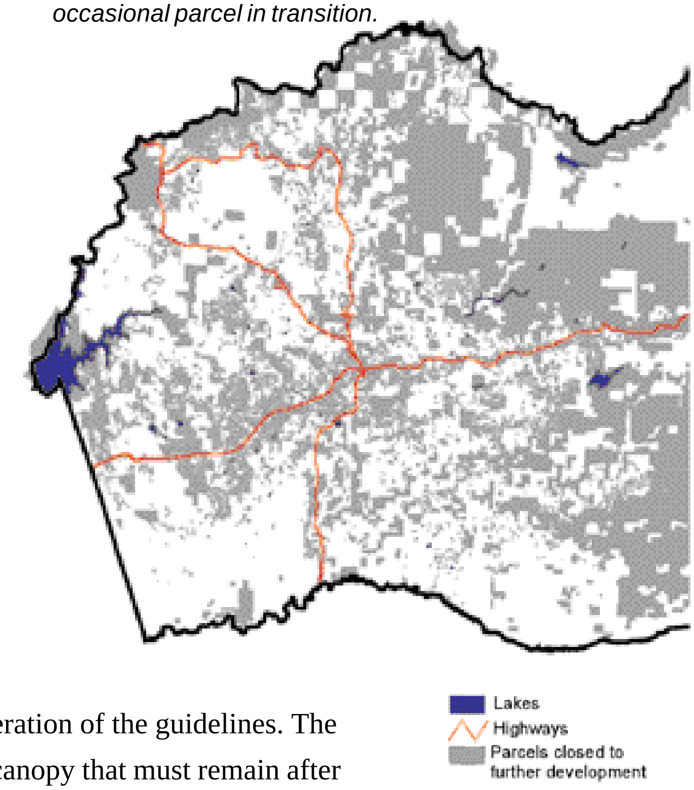
All parcels that are developed and closed—developed parcels at or near the parcel size specified by the General Plan (Figure 4.2)—cannot accept further development and are therefore included in the *no build area*. The non-urban and non-other pixels within these parcels represent in some measure the contribution of current residents to habitat conservation.

Steep slope and streamside set-asides

Some General Plan policies limit the location of development within otherwise developable parcels. General Plan policies proscribe development within 100 feet of streams and on slopes greater than 40 percent and require certain levels of canopy retention for all projects subject to *discretionary review*. Generally, building permits do not fall under discretionary review, but Tentative Maps, Parcel Subdivisions, Special Use Permits and other Permits granted by the Planning Department are considered discretionary. Consequently, modeling the effect of these exclusions requires a delineation of where development will require discretionary permit review.

The El Dorado County parcel data permits a classification of parcels into categories of *open with restriction*; i.e., subject to discretionary review, or *open without restriction*; i.e., requiring only a building permit. Within parcels that were *open with restriction*, areas within 150 feet of a stream (as shown in USGS data) or having a 40 percent or greater slope (according to the digital elevation model of the county) were considered unbuildable and entered into the no build grid (see Figure 4.3). The analysis uses a two-pixel stream buffer which, because pixels are 25-m squares, translates to 150 feet rather than the 100-foot buffer called for in Plan policies. Thus, the analysis slightly over-estimates the protection provided by the General Plan.

Figure 4.2 Parcels closed to further development. All parcels that are currently closed (vacant or developed) receive no further development. In this case closed parcels include all "unassigned" parcels: road, public lands and the occasional parcel in transition.

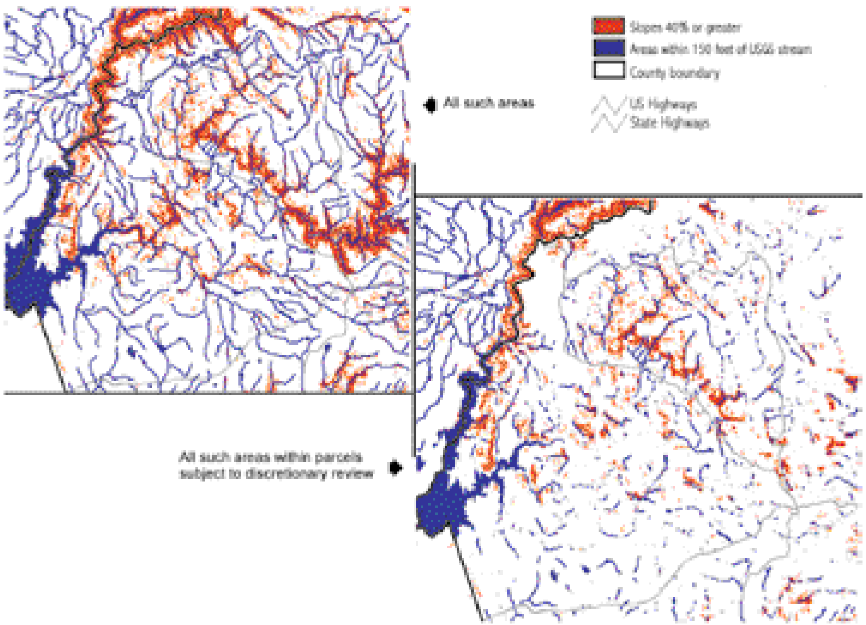


General Plan canopy retention guidelines, as described by the Planning Department, create two situations that require quite different approaches. In certain cases, the retention guidelines call for complete canopy retention. In those areas, the policy prohibits development of all oak woodland; therefore, those oak woodland pixels become part of the no build grid. In other cases, the retention guidelines specify the percentage of existing canopy that must remain after development. Modeling of these cases proceeds, not by pulling pixels into the no build grid, but by altering B values where needed to reflect the operation of the guidelines. The canopy retention guidelines—the proportion of canopy that must remain after development—is the complement of B, the proportion of canopy that will be converted within a given LUDES class. In some areas, the proportion left unconverted by development may be larger than the canopy retention guidelines. In that case, the guidelines would not constrain development. However, if the proportion of the area left unconverted drops below the canopy retention guidelines, then the guideline would act to constrain development. In these areas, the guidelines, rather than General Plan LUDES, set the degree of conversion.

Unlike the analysis given to other restrictions, the treatment of canopy retention guidelines uses map book pages rather than individual parcels as the spatial framework. Mis-registration between parcel and land cover pixel data could lead to many erroneous calls with respect to combinations of LUDES and existing canopy cover for individual parcels. By adopting the larger unit of a map book page, and labeling each according to LUDES and existing canopy cover, the analysis reproduces the average impact of the guidelines over this larger unit.

Map book pages are literally pages within Assessor map books which show the relative location of a number (1-99) of adjacent and historically related parcels. The Map Book Page dataset contains fields that record the number of parcels in different sizes classes within each map book page. Map book pages can generally be associated with a General Plan Land Use Designation (LUDES) through an overlay with the General Plan (Figure 4.4).

Figure 4.3 Steep slopes and streamside areas for a portion of the western slope of El Dorado County. Existing parcel sizes strongly limit the extent of steep slopes and streamside areas that are protected from development by the General Plan policies on discretionary projects. (Protection through public ownership or closed parcel status not shown.)



This analysis labels each map book page as either subject to discretionary review or not. Map book pages within which further development is subject to discretionary project review, and therefore to canopy retention guidelines, are those for which their LUDES have at least some parcels large enough to merit further subdivision before building commences. Table 4.1 lays out those size criteria.

The exclusion of non-residential map book pages (e.g., Industrial, Commercial, Public Facilities, Research and Development and Tourist Facilities) from the set of map book pages within which General Plan policies apply may not introduce serious errors. The guidelines are probably not applicable to these land uses. Beyond that, it is impossible to differentiate those map book pages labeled with non-residential LUDES that would require discretionary permit review from those that do not require such a permit. The choice is then either to include or to exclude all such map book pages. This analysis excludes such pages, which may underestimate the impact of General Plan policies. However, as Figure 4.5 shows, the extent of that underestimation is probably not great.

The General Plan canopy retention guidelines specify the percentage of existing canopy that must remain after the project for all unique combinations of residential LUDES and existing canopy closure (Table 4.2). The analysis cannot distinguish all the combinations of LUDES and existing canopy closure because: (1) the analysis lumps high density residential (HDR) and multifamily residential (MFR) in a single high impact class, and (2) the hardwood pixel data distinguishes only four classes of density. Table 4.3 contains the canopy retention percentages translated into categories of land use and canopy closure permitted by the data.

Table 4.1 Criteria by which map book pages were designated as areas within which General Plan policies would apply.

LUDES and density thresholds	Criteria for application of GP policies	Code to select set from Map book page dataset
Rural Residential (RR) >10 acres/unit	Must have at least one parcel greater than 40 acres	([Ludes] = "RR") and NOT {([Ge40lt160_] = 0) and ([Ge160lt640] = 0) and ([Ge640_ct] = 0)}
Low Density Residential (LDR) 5-10 acres/unit	Must have at least one parcel greater than 20 acres	([Ludes] = "LDR") and NOT {([Ge20lt40_c] = 0) and ([Ge40lt160_] = 0) and ([Ge160lt640] = 0) and ([Ge640_ct] = 0)}
Medium Density Residential (MDR) 1-5 acre/unit	Must have at least one parcel greater than 10 acres	([Ludes] = "MDR") and NOT {(Ge10lt20_c] = 0) and ([Ge20lt40_c] = 0) and ([Ge40lt160_] = 0) and ([Ge160lt640] = 0) and ([Ge640_ct] = 0)}
High Density Residential (HDR) <1 acre/unit	Must have at least one parcel greater than 5 acres	([Ludes] = "HDR") and NOT {([Ge5lt10_ct] = 0) and ([Ge10lt20_c] = 0) and ([Ge20lt40_c] = 0) and ([Ge40lt160_] = 0) and ([Ge160lt640] = 0) and ([Ge640_ct] = 0)}
Multi-Family Residential (MFR)	All pages labeled as MFR	([Ludes] = "MFR")
Adopted Plan (AP)	All pages labeled as AP	([Ludes] = "AP")
Other LUDES	Not included	Absence of density thresholds for non-residential LUDES renders impossible any selection from within Map book page dataset

Table 4.2 Percent canopy retention pursuant to General Plan Policy 7.4.4.4 for combinations of land use designation and existing canopy closure.

	Current Canopy Closure (percent)				
LUDES	≤ 19	20-39	40-59	60-79	80-100
Rural residential	100	100	100	95	90
Low density residential	100	100	90	85	80
Medium density residential	100	90	80	70	65
High density residential	100	90	80	70	65
Multi-family density	90	85	80	70	60

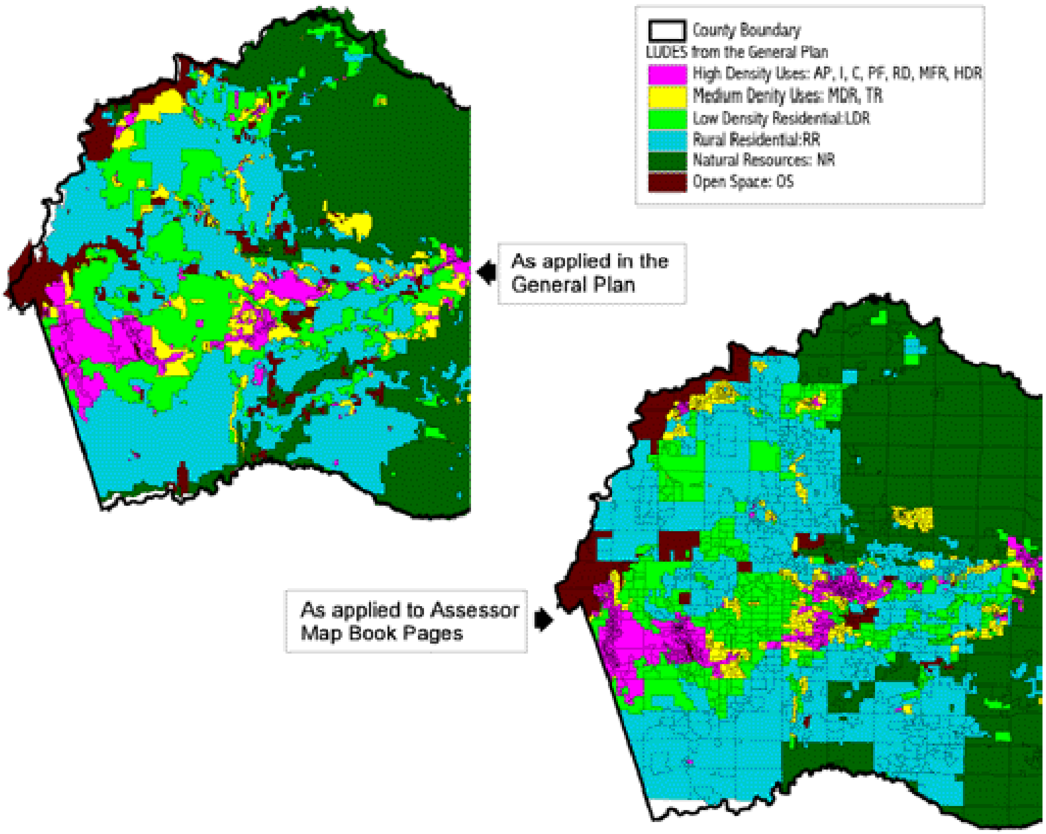
Table 4.3. Percent canopy used in analysis of map book pages characterized by combinations of land use designation and existing canopy closure.

	Current Canopy Closure (percent)			
LUDES	≤19	20-39	40-59	60-100
Rural residential	100	100	100	92.5
Low density residential	100	100	90	82.5
Medium density residential	100	90	80	67.5
High density residential, multi-family residential and Adopted Plan	100	90	80	67.5

Table 4.4 Percent of landscape expected to remain undeveloped at buildout (1-B), and percent canopy retention used in simulation for map book pages characterized by combinations of land use designations and existing canopy closure. Cases in green are those that require 100 percent. Cases in red are those in which canopy retention guidelines constrain development to levels less than otherwise allowable by the General Plan LUDES and its associated B value.

		Current Canopy Closure (percent)			
LUDES	1-B	≤19	20-39	40-59	60-100
Rural residential	.94	100	100	100	92.5
Low density residential	.91	100	100	90	82.5
Medium density residential	.86	100	90	80	67.5
High density residential, Multi-family residential and Adopted Plan	.73	100	90	80	67.5

Figure 4.4. LUDES as shown in the General Plan and as applied to Assessor Map Book Pages. Pulling land use designations from the General Plan to attribute to map book pages yields a close but not identical picture of build out densities.



Certain combinations require complete canopy retention. In subdivision map book pages with those combinations of LUDES and canopy closure class, all hardwood pixels are excluded from development and enter the no build grid. In other cases where development can remove some canopy, the analysis compares the canopy retention guidelines to the retention expected according to the B value associated with the LUDES of the map book page, and uses whichever value is greater. In cases where buildout is expected to remove less canopy than allowed by the guidelines, the analysis projects development according to the B value. In cases where buildout is expected to remove more canopy than allowed by the guidelines, the proportion of land developed at build out (see Appendix 5) is reset to the value required by the guidelines.

This restriction occurs in only a few cases involving MDR and HDR (Table 4.4).

For instance, some subdivision map book pages may manifest a combination of LUDES (e.g., MDR) and canopy closure such that:

LUDES would permit a 14 percent conversion of the landscape to *urban or other*, but

The retention guidelines require that no more than 10 percent of the canopy may be lost.

In these cases, the analysis imposes the more stringent of the two restrictions and simulates within those map book pages a development pattern that converts 10 rather than 14 percent of the landscape. Figure 4.6 portrays the areas where canopy retention guidelines will apply.

Figure 4.5 Map book pages labeled as residential according to LUDES within which canopy retention policies are assumed to apply, as well as non-residential map book pages within which canopy retention quidelines are assumed not to apply. White areas are residential map book pages (as well as NR and OS LUDES) assumed not subject to discretionary review and therefore not subject to canopy retention guidelines.

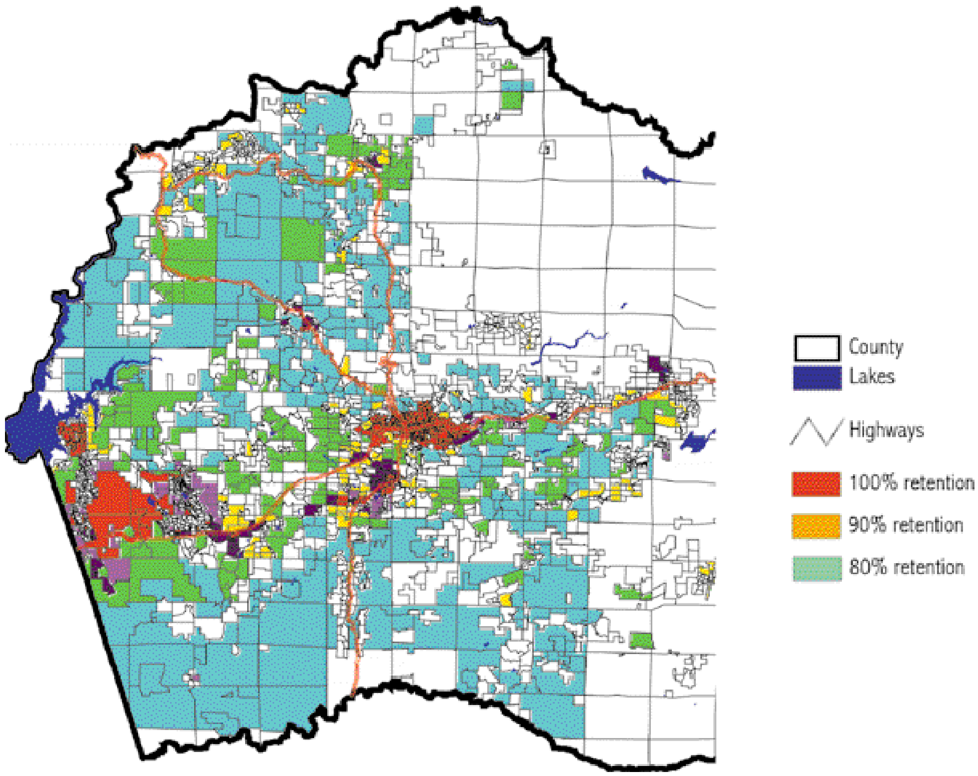
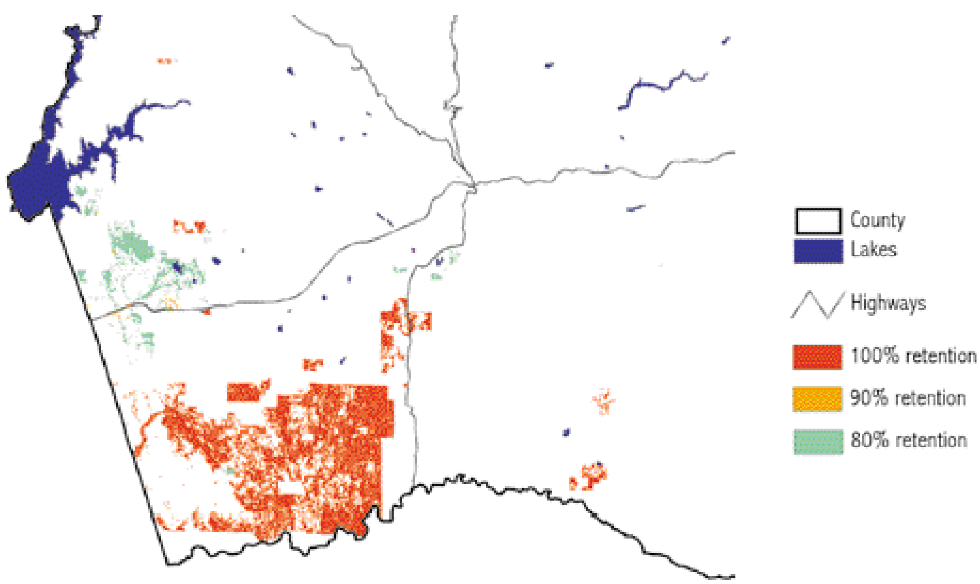


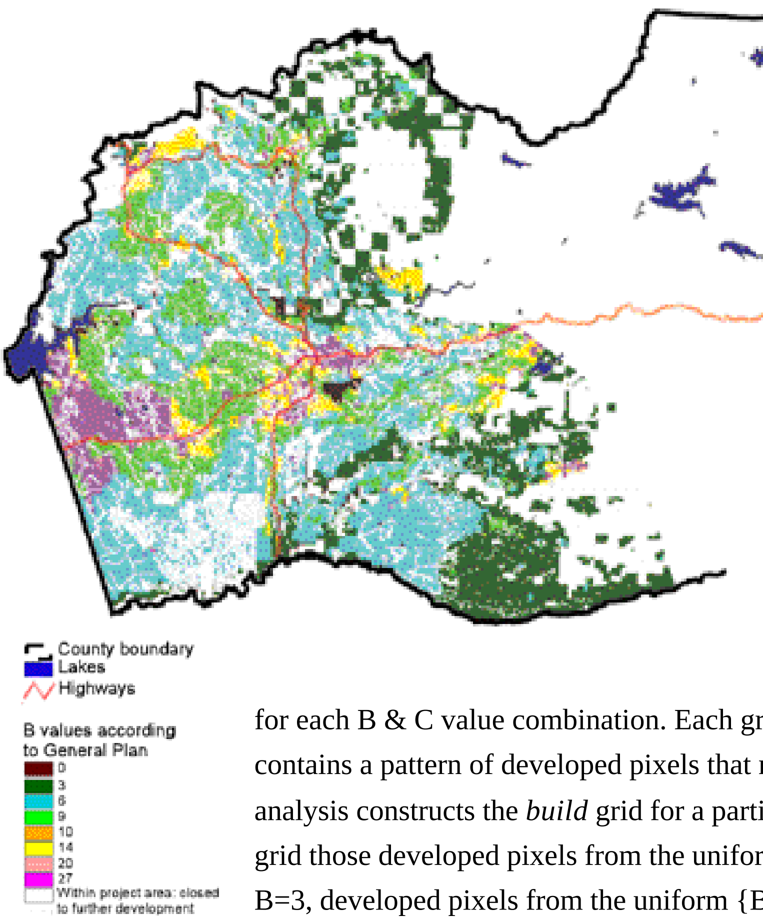
Figure 4.6 Incidence of application and nature of canopy retention guidelines



Appendix 5. Spatial modeling of buildout

Areas that have not been excluded from further development (i.e., outside the no build grid and not already developed)are candidate sites for new development (Figure 5.1). In this analysis, new development is portrayed as the insertion, or simulation, of new *urban or other* pixels. The density and spatial arrangement of those new *urban or other* pixels is controlled by the LUDES attributed to the area by the General Plan, specifically by the B and C values associated with the LUDES. The only exception to this rule occurs in those areas where the B value would remove more canopy than allowed by the retention guidelines. In those areas, new B values associated with the retention guidelines govern the simulation of new developed pixels.

Figure 5.1 Buildable area with associated B values. Unbuildable areas result from government ownership, exclusion of some riparian and steep slopes, and complete retention of hardwood canopy in certain map book pages.



The map of additional development at buildout (or more broadly, the increment of new development associated with any scenario) is assembled by pulling developed pixels from a series of grids, one for each {B,C} combination, according to the B value shown in the map above (Figure 5.2). Prior to scenario projection, the analysis generates *uniform B* grids—one for each B & C value combination. Each grid covers the entire project area and contains a pattern of developed pixels that meets the particular B and C values. This analysis constructs the *build* grid for a particular scenario by bringing into the build grid those developed pixels from the uniform {B=3} grid for those buildable areas with B=3, developed pixels from the uniform {B=6} grids for those buildable areas with B=6, and so on.

The builtout landscape results from adding the build grid to the map of existing landcover. Wherever the build grid shows new development, the land cover label of the corresponding pixel in the existing land cover map is changed to *urban or other*. Otherwise, the land cover labels of the baseline carry through to the builtout landscape.

Figure 5.2 Construction of the build grid